Proc. Roy. Soc. Victoria, 20 (N.S.), Pt. II., 1907.

Art. X.—*The Formation of Red Wood in Conifers.*

By JEAN WHITE, M.Sc.

Read 14th November, 1907].

A series of experiments was carried out by Professor Ewart and Mr. Mason-Jones, on Pinus contorta, and P. cembra, and on Cupressus nutkaensis and C. Lawsoniana, in which certain of the lateral branches were curved round and tied securely for some time, until new wood could be formed. The results of their experiments, published in the "Annals of Botany," April, 1906, led them to conclude that in all probability the formation of red wood was a "morphogenic response to a gravitational stimulus."

Professor Ewart suggested that I should carry the investigations further by noting the effects of diffusing the action of gravity, by causing a plant to rotate on a klinostat.

The plants experimented on were growing in flower pots, and included Araucaria excelsa, Callitris Gunnii, Cedrus deodara, Cryptomeria elegans, Cupressus sempervirens, Juniperus phœnicea, Pinus strobus, Podocarpus elata, Sequoia sempervirens, Taxus baccata, Thuja orientalis.

On 20th September, 1906, the Cupressus was put on to the klinostat, which was set rotating at the rate of one turn in four hours. The remaining plants were laid down horizontally on their sides, in a glass-house, the upper side of each pot being marked. The plants had been previously tied to long stakes, so as to relieve the pressure on the under side.

The plants were all examined on 28th November, 1906, and the following results were noted:—In Araucaria excelsa, Cryptomeria elegans, Juniperus phœnicea, Pinus strobus, Podocarpus elata, Sequoia sempervirens, and Taxus baccata, there was an extremely well-marked layer of red wood developed on the under side of the stem, as it lay horizontally. Also the red wood was very conspicuous on the under surface of all the lateral branches which were examined.

In Callitris gunni, Cedrus deodara and Thuja orientalis, there was a less conspicuous layer of red tracheides produced on the under surface of the main stem and its branches.

The Cupressus sempervirens was also removed from the klinostat on 28th November, 1906.

During the two months' rotation, there were two stoppages of the klinostat for a possible duration of 16 hours and 3 hours respectively. Examination showed a uniform exceedingly faint layer of red wood round the main stem and lateral branches. The Cupressus plant had two similar main stems, one of which was examined when it was first removed from the klinostat, and the other one after it was removed for the second time.

The Cupressus plant was replaced on the klinostat on 29th November, 1906, the speed of rotation being changed to one revolution in two minutes. It was kept on the klinostat till 28th December, during which time there was a stoppage of the machine possibly for 30 hours. On examination of the stem, after removal of the plant from the klinostat on 28th December, no red wood was visible. Evidently, therefore, to produce any permanent impression upon the developing cambial segments, the gravitational stimulus must last at least 1 to 2 hours. One minute's stimulation is either not perceived, or leaves the segment cell in a labile condition, continually reversed by the completion of each rotation without producing any permanent and definite morphogenic response.

The pot containing the Cupressus plant was laid on its side in the glass-house on 25th January, 1907, the upper side of the flower pot being marked. It was left in this position till 18th October, 1907. On stripping off the bark, a thick layer of red wood, about 20 tracheides deep, was observed on the under surface of the main steam and lateral branches.

The above results serve to strengthen Professor Ewart's and Mr. Mason-Jones' conclusions as to the primary stimulus responsible for the production of the red wood, being a gravitational one.

Diameter of the Xylem Vessels, and Thickness of Their Walls.

The diameters of the cavities of the vessels, and also the thickness of the vessel walls were measured by means of the screw micrometer eyepiece, in both the red and white wood. Sections were cut of the main stems of several of the plants, which had been growing in the pots placed on their sides from 20th September to 28th November, 1906.

Taking the averages of the thickness of the walls in the red and white wood, the two sets of readings being taken from the same section as nearly diametrically opposite as possible, in practically every case, the walls of the white tracheides were found to be thicker than those of the red, whilst the cavities of the tracheides of the white wood were smaller in diameter than those of the red tracheides.

These results are not in accordance with those previously recorded by Sonntag,[1] who found that the walls of the tracheides in the red wood were thicker than those of the white.

Experimental Results.

A number of readings were taken of the internal diameters and the thickness of the walls of the tracheides, and the results are given in the form of averages of sets of five readings, followed by averages of these again.

Taxus baccata.

In the thickest part of the red wood in the sections examined, the tracheides were 20 deep.

SECTION I.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.008 mm.	.004 mm.	.008 mm.	.008 mm.
.009 ,,	.004 ,,	.008 ,,	.008 ,,
.011 ,,	.004 ,,	.008 ,,	.007 ,,
.012 ,,	.005 ,,	.009 ,,	.007 ,,
Average	Average	Average	Average
.010 mm.	.004 mm.	.008 mm.	.008 mm.

1 Jahrb. für wiss, Bot., Bd. xxxix., p. 71.

Section II.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.011 mm.	.006 mm.	.007 mm.	.005 mm.
.008 ,,	.006 ,,	.008 ,,	.006 ,,
.010 ,,	.006 ,,	.008 ,,	.007 ,,
.010 ,,	.006 ,,	.007 ,,	.005 ,,
.009 ,,	.006 ,,	.008 ,,	.008 ,,
.011 ,,	.007 ,,	.011 ,,	.007 ,,
Average	Average	Average	Average
.009 mm.	.006 mm.	.008 mm.	.006 mm.

Section III.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thicknes of Wall
.008 mm.	.006 mm.	.006 mm.	.008 mm.
.008 ,,	.007 ,,	.009 ,,	.008 ,,
.011 ,,	.008 ,,	.007 ,,	.006 ,,
.008 ,,	.005 ,,	.008 ,,	.007 ,,
.007 ,,	.005 ,,	.009 ,,	.007 ,,
.010 ,,	.004 ,,	.008 ,,	.006 ,,
Average	Average	Average	Average
.008 mm.	.006 mm.	.008 mm.	.007 mm.

Pinus strobus.

Section I.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.016 mm.	.005 mm.	.014 mm.	.005 mm.
.011 ,,	.003 ,,	.012 ,,	.005 ,,
.012 ,,	.004 ,,	.014 ,,	.003 ,,
Average	Average	Average	Average
013 mm.	.004 mm.	.013 mm.	.004 mm.

Section II.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.015 mm.	.004 mm.	.014 mm.	.005 mm.
.014 ,,	.004 ,,	.015 ,,	.005 ,,
.012 ,,	.005 ,,	.012 ,,	.005 ,,
Average	Average	Average	Average
.014 mm.	.004 mm.	.014 mm.	.005 mm.

Araucaria excelsa.

Section I.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.017 mm.	.007 mm.	.017 mm.	.009 mm.
.017 ,,	.007 ,,	.018 ,,	.009 ,,
.020 ,,	.007 ,,	.016 ,,	.009 ,,
Average	Average	Average	Average
.018 mm.	.007 mm.	.017 mm.	.009 mm.

Section II.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.016 mm.	.006 mm.	.020 mm.	.009 mm.
.018 ,,	.008 ,,	.017 ,,	.009 ,,
.017 ,,	.007 ,,	.016 ,,	.008 ,,
Average	Average	Average	Average
.017 mm.	.007 mm.	.018 mm.	.009 mm.

Podocarpus elata

Section 1.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.014 mm.	.007 mm.	.008 mm.	.007 mm.
.011 ,,	.005 ,,	.011 ,,	.007 ,,
Average	Average	Average	Average
.012 mm.	.006 mm.	.009 mm.	.007 mm.

Section II.

Red Wood.		White Wood.	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.012 mm.	.009 mm.	.008 mm.	.007 mm.
.012 ,,	.005 ,,	.011 ,,	.007 ,,
Average	Averege	Average	Average
.012 mm.	.007 mm.	.009 mm.	.007 mm.

Summary of Preceding Results.

The plants were placed horizontally, the upper side being the more strongly illuminated.

	Thickness of Walls		Internal Diameter	
	Red Wood	White Wood	Red Wood	White Wood
Taxus baccata.				
	.004 mm.	.008 mm.	.010 mm.	.008 mm.
	.006 ,,	.006 ,,	.009 ,,	.008 ,,
	.006 ,,	.007 ,,	.008 ,,	.008 ,,
	Average	Average	Average	Average
	.0053 mm.	.0070 mm.	.0090 mm.	.0080 mm.
Pinus strobus.				
	.004 ,,	.004 ,,	.013 ,,	.013 ,,
	.004 ,,	.005 ,,	.014 ,,	.014 ,,
	Average	Average	Average	Average
	.0040 mm.	.0045 mm.	.0135 mm.	.0135 mm.
Araucaria excelsa.				
	.007 ,,	.009 ,,	.018 ,,	.017 ,,
	.007 ,,	.009 ,,	.017 ,,	.018 ,,
	Average	Average	Average	Average
	.0070 mm.	.0090 mm.	.0175 mm.	.0175 mm.
Podocarpus elata.				
	.006 ,,	.007 ,,	.012 ,,	.009 ,,
	.007 ,,	.007 ,,	.012 ,,	.009 ,,
	Average	Average	Average	Average
	.0065 mm.	.0070 mm.	.0120 mm.	.0090 mm.

The above results appeared to indicate that the thickness of the tracheide walls might be influenced by either pressure or illumination, or both.

In order to investigate this matter further, some of the lateral branches of Cedrus deodara, Thuja orientalis, Callitris Gunnii, Cryptomeria elegans, and Pinus strobus, were curved round and tied in the same manner as were those described by Professor Ewart and Mr. Mason-Jones.[1] The plants were set upright in the glass-house on 21st May, 1907. Parts of the lateral branches of Taxus baccata, Podocarpus elata, and Araucaria excelsa were bound round with tinfoil, and the pots were laid horizontally in the glass-house, and the uppermost part of the pot marked, also on 21st May, 1907.

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1 Annals of Botany, vol. xx., p. 202.

On 10th August, 1907, some of these plants were examined. Very conspicuous layers of red wood were developed on the under surface of both parts of the curve, just as described in the "Annals of Botany." Sections were cut from the parts of the curve where the development of red wood was greatest, and the internal diameters of the red and white tracheides, and also the thickness of their walls, were measured.

Experimental Results.

Pinus strobus.

SECTION I.—(From upper portion of curve).

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.008 mm.	.003 mm.	.012 mm.	.006 mm.
.010 ,,	.002 ,,	.012 ,,	.006 ,,
.009 ,,	.003 ,,	.010 ,,	.006 ,,
.010 ,,	.002 ,,	.010 ,,	.007 ,,
Average	Average	Average	Average
.009 mm.	.003 mm.	.011 mm.	.006 mm.

SECTION II.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.009 mm.	.003 mm.	.008 mm.	.005 mm.
.012 ,,	.003 ,,	.010 ,,	.006 ,,
.012 ,,	.002 ,,	.009 ,,	.006 ,,
.009 ,,	002 ,,	.010 ,,	.007 ,,
Average	Average	Average	Average
010 mm.	.003 mm.	.009 mm.	.006 mm.

SECTION III.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.009 mm.	.002 mm.	.008 mm.	.006 mm.
.013 ,,	.003 ,,	.010 ,,	.006 ,,
.008 ,,	.002 ,,	.009 ,,	.006 ,,
Average	Average	Average	Average
.009 mm.	.002 mm.	.009 mm.	.006 mm.

Callitris gunni.

Section I.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.012 mm.	.002 mm.	.009 mm.	.004 mm.
.006 ,,	.002 ,,	.008 ,,	.003 ,,
.009 ,,	.003 ..	.008 ,,	.005 ,,
.009 ,,	.002 ,,	.008 ,,	.003 ,,
Average	Average	Average	Average
.008 mm.	.002 mm.	.008 mm.	.002 mm.

Section II.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.009 mm.	.004 mm.	.009 mm.	.005 mm.
.006 ,,	.002 ,,	.006 ,,	.004 ,,
.008 ,,	.001 ,,	.006 ,,	.003 ,,
.008 ,,	.002 ,,	.008 ,,	.003 ,,
Average	Average	Average	Average
.008 mm.	.002 mm.	.007 mm.	.003 mm.

Cryptomeria elegans.

Section I.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.006 mm.	.002 mm.	.006 mm.	.005 mm.
.007 ,,	.001 ,,	.006 ,,	.004 ,,
.008 ,,	.001 ,,	.008 ,,	.006 ,,
.008 ,,	.002 ..	.009 ,,	.005 ,,
Average	Average	Average	Average
.007 mm.	.002 mm.	.007 mm.	.005 mm.

Section II.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.007 mm.	.002 mm.	.006 mm.	.005 mm.
.009 ,,	.002 ,,	.006 ,,	.006 ,,
.008 ,,	.001 ,,	.008 ,,	.005 ,,
.010 ,,	.002 ,,	.009 ,,	.003 ,,
Average	Average	Average	Average
.009 mm.	.002 mm.	.008 mm.	.005 mm.

Summary of Preceding Results.

The stems were bent in curves. The white wood side was under tension, and was the more strongly illuminated side.

PINUS STROBUS.

Thickness of Walls		Internal Diameter	
Red Wood	White Wood	Red Wood	White Wood
.003 mm.	.006 mm.	.009 mm.	.011 mm.
.003 ,,	.006 ,,	.010 ,,	.009 ,,
.002 ,,	.006 ,,	.009 ,,	.009 ,,
Average	Average	Average	Average
.0028 mm.	.0060 mm.	.0091 mm.	.0093 mm.
CALLITRIS GUNNI.			
.002 ,,	.003 ,,	.008 ,,	.008 ,,
.002 ,,	.003 ,,	.008 ,,	.008 ,,
Average	Average	Average	Average
.0020 mm.	.0030 mm.	.0080 mm.	.0080 mm.
CRYPTOMERIA ELEGANS.			
.002 ,,	.005 ,,	.007 ,,	.007 ,,
.002 ,,	.005 ,,	.009 ,,	.008 ,,
Average	Average	Average	Average
.0020 mm.	.0050 mm.	.0080 mm.	.0075 mm.

On August 16th 1907, the lateral branches which had been covered with tinfoil were examined. A layer of red wood was observed on the under side of the branches which had been covered with tinfoil, as before. Hence Sonntag is incorrect in supposing that heliotropic or pressure stimuli are responsible for the formation of redwood. Sections of the lateral branches which were covered were cut, and the thickness of the tracheide walls and their internal diameters were measured.

Experimental Results.

Taxus baccata.

SECTION I.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.010 mm.	.001 mm.	.008 mm.	.005 mm.
.008 ,,	.002 ,,	.005 ,,	.002 ,,
.009 ,,	004 ,,	.007 ,,	.002 ,,
.009 ,,	.004 ,,	.006 ,,	.003 ,,
Average	Average	Average	Average
.009 mm.	.003 mm.	.006 mm.	.003 mm.

SECTION II.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.009 mm.	.004 mm.	.008 mm.	.005 mm.
.007 ,,	.004 ,,	.005 ,,	.005 ,,
.008 ,,	.004 ,,	.006 ,,	.005 ,,
.008 ,,	.005 ,,	.006 ,,	.004 ,,
Average	Average	Average	Average
.008 mm.	.004 mm.	.006 mm.	.004 mm.

Podocarpus elata.

SECTION I.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.010 mm.	.002 mm.	.009 mm.	.001 mm.
.016 ,,	.004 ,,	.009 ,,	.004 ,,
.012 ,,	.006 ,,	.012 ,,	.005 ,,
.009 ,,	.005 ,,	.010 ,,	.005 ,,
Average	Average	Average	Average
.011 mm.	.004 mm.	.010 mm.	.004 mm.

SECTION II.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.010 mm.	.003 mm.	.012 mm.	.003 mm.
.009 ,,	.007 ,,	.013 ,,	.005 ,,
.008 ,,	.006 ,,	.012 ,,	.005 ,,
.009 ,,	.005 ,,	.012 ,,	.008 ,,
Average	Average	Average	Average
.009 mm.	.005 mm.	.012 mm.	.005 mm.

SECTION III.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.013 mm.	.003 mm.	.013 mm.	.003 mm.
.015 ,,	.005 ,,	.015 ,,	.005 ,,
.010 ,,	.006 ,,	.010 ,,	.006 ,,
.008 ,,	.003 ,,	.008 ,,	.003 ,,
Average	Average	Average	Average
.011 mm.	.004 mm.	.011 mm.	.004 mm.

Araucaria excelsa.

SECTION I.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.013 mm.	.003 mm.	.022 mm.	.003 mm.
.010 ,,	.001 ,,	.016 ,,	.004 ,,
.010 ,,	.002 ,,	.015 ,,	.003 ,,
.010 ,,	.003 ,,	.013 ,,	.003 ,,
Average	Average	Average	Average
.011 mm.	.002 mm.	.014 mm.	.003 mm.

SECTION II.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.016 mm.	.005 mm.	.020 mm.	.005 mm.
.021 ,,	.004 ,,	.016 ,,	.003 ,,
.017 ,,	.005 ,,	.016 ,,	.006 ,,
.018 ,,	.006 ,,		
Average	Average	Average	Average
.018 mm.	.005 mm.	.017 mm.	.005 mm.

SECTION III.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.013 mm.	.005 mm.	.013 mm.	.004 mm.
.018 ,,	.008 ,,	.023 ,,	.006 ,,
.006 ,,	.005 ,,	.013 ,,	.003 ,,
.016 ,,	.006 ,,	.020 ,,	.005 ,,
Average	Average	Average	Average
.013 mm.	.006 mm.	.017 mm.	.005 mm.

Summary of Preceding Results.

Both sides were equally darkened. The red wood side was under compression, and the white wood side was under tension.

TAXUS BACCATA.

Thickness of Walls		Internal Diameter	
Red Wood	White Wood	Red Wood	White Wood
.003 mm.	.003 mm.	.009 mm.	.006 mm.
.004	.004 ,,	.008 ,,	.006 ,,
Average	Average	Average	Average
.0035 mm.	.0035 mm.	.0085 mm.	.0060 mm.

PODOCARPUS ELATA.

.004 ,,	.004 ,,	.011 ,,	.010 ,,
.005 ,,	.005 ,,	.009 ,,	.012 ,,
.004 ,,	.004 ,,	.011 ,,	.011 ,,
Average	Average	Average	Average
.0043 mm.	.0043 mm.	.0101 mm.	.0110 mm.

ARAUCARIA EXCELSA.

.002 ,,	.003 ,,	.011 ,,	.014 ,,
.005 ,,	.005 ,,	.018 ,,	.017 ,,
.006 ,,	.005 ,,	.013 ,,	.017 ,,
Average	Average	Average	Average
.0043 mm.	.0043 mm.	.0140 mm.	.0490 mm.

These sections, taken from the curved lateral branches, were all cut from the upper portion of the curve, so that the red wood vessels were subjected to compression, and the white wood vessels were subject to tension.

Concerning the thickness of the walls, the ratio of the thickness of the white to the red tracheides is not very different from their ratio when they were not subjected to any special pressure, and so, presumably, the thickness of the walls does not to any appreciable extent depend on pressure effects of the intensity produced by forcibly bending a stem into circular form or laying a vertical stem in a horizontal position. Also in those sections, cut from the parts of the branches covered with tinfoil, in practically every case, it was found that the thickness of the walls of red wood vessels and white wood vessels was the same, which indicates that photomorphic stimuli take an important part in the regulation of the thickness of the walls. In this respect my experiments appear to agree with those of Knight,[1] who found, for instance, that roots freed from soil and exposed to light formed firmer wood.

The Cryptomeria, Callitris and Pinus had some of their lateral branches curved and tied round in the manner described previously, the upper part of the curve being covered over with tinfoil. They were placed upright in the glass-house on 16th August, 1907.

Measurements of the diameters of the red and white wood vessels, and of their walls, were taken on 4th November, 1907.

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1 Pfeffer's Physiology of Plants, English Translation. Vol. ii., page 88.

Experimental Results.

Callitris Gunnii.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.009 mm.	.005 mm.	.008 mm.	.005 mm.
.008 ,,	.005 ,,	.009 ,,	.008 ,,
.008 ,,	.006 ,,	.008 ,,	.005 ,,
.009 ,,	.005 ,,	.006 ,,	.005 ,,
Average	Average	Average	Average
.008 mm.	.005 mm.	.008 mm.	.006 mm.

Cryptomeria elegans.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.005 mm.	.006 mm.	.006 mm.	.005 mm.
.008 ,,	.006 ,,	.005 ,,	.005 ,,
.005 ,,	.004 ,,	.005 ,,	.004 ,,
.006 ,,	.004 ,,	.005 ,,	.004 ,,
Average	Average	Average	Average
.006 mm.	.005 mm.	.005 mm.	.005 mm.

Pinus strobus.

Red Wood		White Wood	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.010 mm.	.006 mm.	.009 mm.	.008 mm.
.010 ,,	.008 ,,	.008 ,,	.008 ,,
.012 ,,	.005 ,,	.013 ,,	.005 ,,
.009 ,,	.006 ,,	.010 ,,	.005 ,,
Average	Average	Average	Average
.010 mm.	.006 mm.	.010 mm.	.006 mm.

Summary of Preceding Experiments.

Internal Diameter		Thickness of Walls	
Red Wood	White Wood	Red Wood	White Wood
Callitris gunni.			
.008 mm.	.008 mm.	.005 mm.	.006 mm.
Cryptomeria elegans.			
.006 ,,	.005 ,,	.005 ,,	.005 ,,

PINUS STROBUS.

.010 mm.	.006 mm.	.010 mm.	.006 mm.

A large branch of Cupressus sempervirens with sufficient bark and phloem to cut off nearly all light from the cambium was removed from the tree on which it was growing normally. An extremely thick layer of red wood was visible on the under side of the branch as it grew.

Sections of the red and white wood were examined, and the diameters of the cavities, and the thickness of the walls of the xylem vessels in each kind were measured, with the following results : —

RED WOOD		WHITE WOOD	
Internal Diameter	Thickness of Wall	Internal Diameter	Thickness of Wall
.012 mm.	.004 mm.	.016 mm.	.006 mm.
.016 ,,	.004 ,,	.016 ,,	.005 ,,
.012 ,,	.005 ,,	.013 ,,	.005 ,,
015 ,,	.005 ,,	.018 ,,	.005 ,,
Average	Average	Average	Average
.0143 mm.	.0045 mm.	.0156 mm.	.0052 mm.

In this case the difference between the intensity of the illumination on the upper (white wood) and the lower (red wood) surface must be extremely small, and the average thickness of the white wood walls is little or not at all greater than in the red wood.

Summary of Preceding Experiments.

THICKNESS OF WALLS		INTERNAL DIAMETER	
Red Wood	White Wood	Red Wood	White Wood
.0160 mm.	.0052 mm.	.0140 mm.	.0045 mm.

Pinus strobus.

Plant grown horizontally.
White wood on illuminated side.

THICKNESS OF WALLS		INTERNAL DIAMETER	
Red Wood	White Wood	Red Wood	White Wood
Average	Average	Average	Average
.0040 mm.	.0045 mm.	.0135 mm.	.0135 mm.

Plant grown vertically.

Curved stem. Red wood compressed. White wood stretched and illuminated.

Thickness of Walls		Internal Diameter	
Red Wood Average	White Wood Average	Red Wood Average	White Wood Average
.0033 mm.	.0060 mm.	.0093 mm.	.0096 mm.

Curved stem. Both sides equally darkened.

Thickness of Walls		Internal Diameter	
Red Wood Average	White Wood Average	Red Wood Average	White Wood Average
.0060 mm.	.0060 mm.	.0100 mm.	.0100 mm.

Araucaria excelsa.

Plant grown horizontally.

White wood on the illuminated side.

Thickness of Walls		Internal Diameter	
Red Wood Average	White Wood Average	Red Wood Average	White Wood Average
.0070 mm.	.0090 mm.	.0175 mm.	.0175 mm.

Plant grown upright.

Both sides equally darkened.

Thickness of Walls		Internal Diameter	
Red Wood Average	White Wood Average	Red Wood Average	White Wood Average
.0043 mm.	.0043 mm.	.0140 mm.	.0160 mm.

Podocarpus elata.

Plant grown horizontally.

Whited wood on the illuminated side.

Thickness of Walls		Internal Diameter	
Red Wood Average	White Wood Average	Red Wood Average	White Wood Average
.0065 mm.	.0070 mm.	.0120 mm.	.0090 mm.

Plant grown upright.
Both sides equally darkened.

Thickness of Walls		Internal Diameter	
Red Wood	White Wood	Red Wood	White Wood
Average	Average	Average	Average
.0043 mm.	.0043 mm.	.0103 mm.	.0110 mm.

Taxus baccata.

Plant grown horizontally.
White wood on the illuminated side.

Thickness of Walls		Internal Diameter	
Red Wood	White Wood	Red Wood	White Wood
Average	Average	Average	Average
.0053 mm.	.0070 mm.	.0090 mm.	.0080 mm.

Plant grown vertically.
Both sides equally darkened.

Thickness of Walls		Internal Diameter	
Red Wood	White Wood	Red Wood	White Wood
Average	Average	Average	Average
.0035 mm.	.0035 mm.	.0085 mm.	.0060 mm.

Cryptomeria elegans.

Plant grown vertically.
Lateral branches curved. White wood on illuminated side.

Thickness of Walls		Internal Diameter	
Red Wood	White Wood	Red Wood	White Wood
Average	Average	Average	Average
.0020 mm.	.0050 mm.	.0080 mm.	.0075 mm.

Lateral branches curved. Both sides equally darkened.

Thickness of Walls		Internal Diameter	
Red Wood	White Wood	Red Wood	White Wood
Average	Average	Average	Average
.0050 mm.	.0050 mm.	.0060 mm.	.0050 mm.

Callitris Gunnii.

Plant grown vertically (lateral branches curved).
White wood on the illuminated side.

Thickness of Walls		Internal Diameter	
Red Wood	White Wood	Red Wood	White Wood
		.008 mm.	008 mm.
		.008 ,,	.008 ,,
Average	Average	Average	Average
.0020 mm.	.0030 mm.	.0080 mm.	.0080 mm.

Lateral branches curved. Both sides equally darkened.

Thickness of Walls		Internal Diameter	
Red Wood	White Wood	Red Wood	White Wood
.0080 mm.	.0060 mm.	.0080 mm.	.0050 mm.

Conclusion.

So far as my results dealing with this matter go, they point to the conclusion that the formation of red wood is primarily due to a gravitational stimulus, while the lesser thickness shown by the wall of the red wood tracheides, as compared with that of the white wood tracheides, appears to be largely the result of a photomorphic stimulus, the response being somewhat akin to etiolation in character.

The preceding averages all agree in showing that the thickness of the tracheide walls on the more strongly illuminated side exceeded that of the tracheide walls where the illumination was less intense. The same uniformity, under similar conditions, does not apparently prevail in the size of the internal cavities of the tracheides; thus as a general rule along a single radial row of tracheides, isolated cases occurred in which the internal cavities were of abnormal size in either direction, while such abrupt variations did not appear to occur to any marked extent in the thickness of the tracheide walls of either kind of wood.

Considering the cases in which both sides of the branches were equally darkened, the assumption is strengthened by the fact that in every case tested except one, the thickness of the tracheide walls in both red and white wood tallied exactly.

As in some of the above cases, the parts of the stem which were equally darkened were subjected to unequal pressure or tension, due to the curving round of the branches experimented upon, the thickness of the tracheide walls in red and white wood was the same, it seems to be improbable that pressure and tension of the intensity produced by forcibly curving the branch, exert any pronounced influence on either the thickness of the walls, diameter of the tracheides, or formation of red wood. The latter is purely a response to gravity, and is only accompanied by an increase in the thickness of the walls when the red wood side is the more strongly illuminated one, which is unusual. The minimal period for perception and response, as tested by the method of summation, is two hours. Exposures to gravity of less than two minutes' duration produce no permanently lasting effect.

In conclusion, I wish to record my sincere thanks to Prof. Ewart for his assistance, and also for allowing me the use of the Botanical laboratory at the Melbourne University.